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Improving the Acquisition of Software Intensive Systems

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Software Engineering Measurement and Analysis

This report was prepared for the

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Abstract

Acquisitions of software intensive systems by the Department of Defense (DoD) have often suffered from poor product quality, cost overruns, and schedule slips. In turn, these problems have frequently been linked to the inability of project offices to successfully manage the acquisition of the software components of the systems.

There have been a number of efforts to provide the necessary education and training to improve the skills and capabilities of managers for software intensive acquisitions. However, acquisition problems remain pervasive in the DoD [Cavanaugh 98].

More must be known about the causes and underlying issues surrounding these problems. Specifically, the needs of the acquisition management offices must be better understood to help them improve. This includes a better understanding of how education and training can improve the individual manager's skills and competency related to acquiring such systems.

To elicit these needs, the Software Engineering Institute (SEI) conducted a survey of senior acquisition managers. The survey focused on the performance of their organizations, particularly with respect to a series of skills and competency areas that may affect an organization's ability to successfully acquire software intensive systems.

Results indicate that the program executive officers (PEOs) and program managers (PMs) who completed the survey were reasonably well satisfied with the capabilities of their organizations to acquire software intensive systems. In many cases, however, the source of the expertise for such acquisitions were contractors either supporting the organizations or the prime contractors developing these systems. Comparable expertise often was unavailable in government acquisition organizations themselves. From this fact, the need for government expertise in these acquisitions was noted. In addition, the survey queried participants on the best way to obtain this expertise through education and training.

Finally, recommendations derived from survey results are offered to increase software acquisition education and training opportunities for managers.

1   Introduction

A great many systems being acquired by the Department of Defense (DoD) are heavily dependent upon software. These systems include automated information systems (AIS), weapon systems (WS), and command, control, and communication, intelligence electronic warfare systems (C3IEWS).

Acquisitions of such systems often suffer from continued failure of the acquisition and development efforts to meet cost, schedule, and performance goals. These difficulties have been linked to the inability of both the acquirer and the developer to manage the acquisition process, and the developer to manage the development process, especially where software is involved [OUSD 94].

More than three years ago, Secretary of Defense Cohen's noted in a press conference initiating Acquisition Reform Week [Cohen 97]:

> *The challenge is really to apply new practices to all of our programs across the board—large and small. And we have to make acquisition reform a part of our everyday life. And we have to continue to develop an acquisition workforce, and that's also a challenge because they need to have the skills and tools along with the motivation.*

However, the specific approaches that could result in successful acquisitions have not always been clearly identified or implemented [Cavanaugh 98]. More needs to be known about the issues and causes that can explain varying success in acquisition. Specifically, the needs of the acquisition management offices must be better understood to help them improve their acquisitions of software intensive systems. This includes a better understanding of how education and training can improve the individual manager's skills and competency in acquiring such systems.

To elicit these needs, the Software Engineering Institute (SEI) conducted a survey of senior acquisition managers. The survey focused on the performance of their organizations, especially on needed skills and competencies, and on issues surrounding the training needed to develop them in both the project office staffs and for the senior acquisition managers themselves.

We discuss the results of the survey in this report.[1] While the specific purpose was to better understand the needs of project offices, the results also have wider import with respect to organizational process improvement and acquisition reform. Section 2 briefly describes the survey. Section 3 presents the results in graphical form. In addition, Section 3 explores some general themes common to these participants' responses. In Section 4 we discuss general observations we derived from the survey results. Based on these observations, we give some recommendations to help managers obtain needed software acquisition expertise.

2 Approach

This report is based on a survey of senior acquisition personnel, using a structured, self-administered questionnaire that was available both electronically via the World Wide Web and in paper form (see Appendix). The questions were phrased in both pre-coded "closed ended" and free form "open ended" format, allowing the participants to more fully elaborate on their responses. There was also space for additional written remarks and suggestions for improvements.

The questionnaire was structured into four main question sets. "Your Background in the Acquisition of Software Intensive Systems" includes questions about organizational roles, type of systems acquired, previous experience and training in software acquisition, and personal expertise in software. "About Your Acquisition Organization" includes a series of questions about performance in 32 areas of organizational competency. "Training Issues" asks about quality of software education and training, the need for additional preparation for software acquisitions management, and delivery methods for training. Finally, in "Problems Faced in Acquiring Software Intensive Systems," we asked two overall summary questions about particularly difficult problems and recommendations for improving the acquisition of such systems.

The closed ended responses were summarized with simple descriptive statistics in text and graphical form. The open ended responses were classified by recurring themes, and both sets of results were compared for consistency.

The survey was administered during the Summer of 1998. A total of 81 senior acquisition personnel, approximately 60 percent of those initially queried, completed and returned their questionnaires.

3   Results

3.1   Participant Background

The survey participants were considered to be senior-level managers (Figure 1). Over forty percent were Program Executive Officers (PEOs), with the remainder spread among Program, Project, and Product Managers (PMs) and their deputies. All have had considerable responsibilities for the acquisition of a variety of software intensive systems. As seen in Figure 2, the large majority (over 70%) have participated in acquisitions of weapons systems, while well over a third have acquired automated information systems. Similarly, well over a third have acquired C3IEW systems.
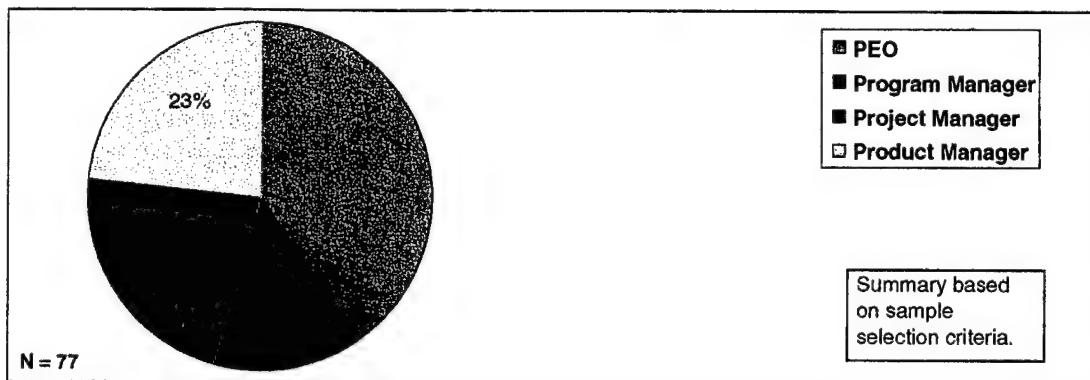
Figure 1:   Organizational Roles
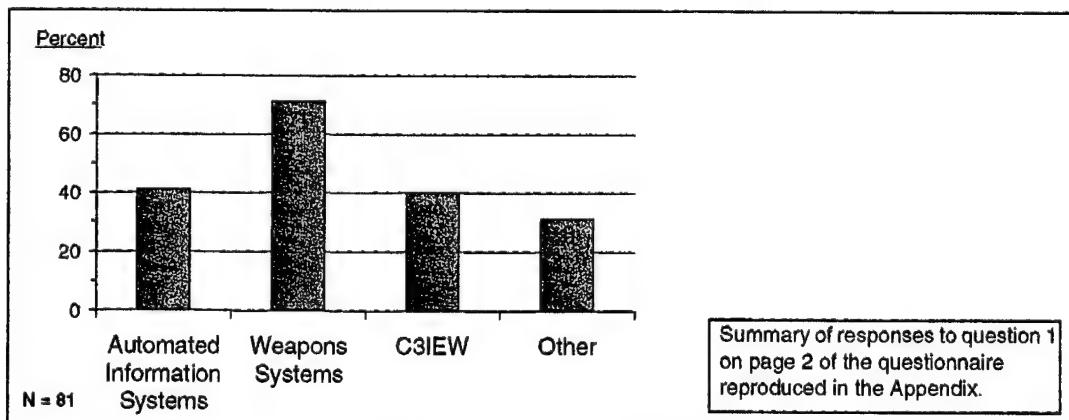
Figure 2:   Systems Acquired by Respondents

3.2　Organizational Performance

We asked the survey participants a broadly stated question about the success of their organizations in acquiring the software for their systems. Most PEOs and PMs rated their organizations reasonably high in their performance in meeting schedule and budget commitments, and the technical performance of the software once deployed. Well over a third of them characterized their organizations' overall performance as excellent or even exceptional (Figure 3).

That said, the plurality (over 40%) did choose the middle category of "good" performance. And a noticeable minority (another 18%) rated their organizations as performing adequately at best.[2]
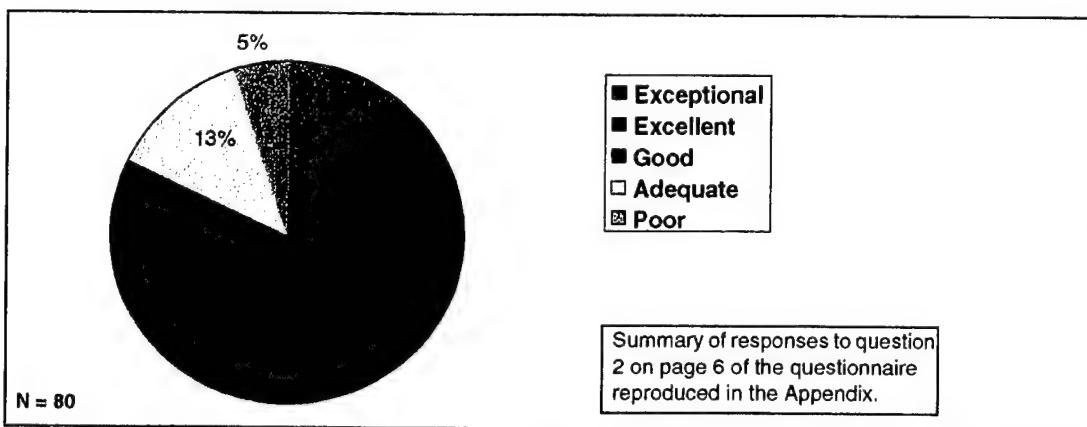
Figure 3:　Performance in Acquiring Software

3.3　Organizational Capability

We asked the survey participants to rate the capabilities of their organizations in each of a series of 22 key competency areas that have been identified by experts as being crucial for the successful acquisition of software intensive systems [Cavanaugh 98]. The responses cannot necessarily be taken as direct measures of "need" for improvement, but they do identify those areas where there may be an audience receptive to change.

The key competency areas are broken down in Figures 4 through 7 according to the rank order in which the participants rated the capability of their acquisition organizations. The areas are ranked from highest to lowest incidence of "poor" and "adequate" responses (with

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2.　There are "social desirability" effects in these kinds of survey data. For example, different ratings might be forthcoming from subordinate staff. In fact, the PEOs in the current study were somewhat more likely to say their organizations did an exceptional or excellent job (46%) than were the PMs (36%).

"unnecessary" indicating the least need for improvement). Figure 4 summarizes the areas asserted to be relatively most in need of improvement. Figure 7 includes the competency areas deemed by the survey participants to be least problematic.

The first thing to notice in the four figures is that these PEOs and PMs generally gave their organizations relatively high competency ratings. However, their responses did vary by competency area, and "good" (i.e., less than "excellent") is almost always the modal category. That pattern of responses typically indicates room for improvement.

Notice in Figure 4 that the largest number of respondents recognized that their organizations had difficulty in providing appropriate training to their personnel. Just over 50% of these PEOs and PMs characterized the training opportunities provided by their organizations as having been poor or adequate at best. Risk management came next, with well over 40% expressing similar reservations about their organizations' capabilities in that area. Cost and schedule estimation were cited similarly by essentially the same number.
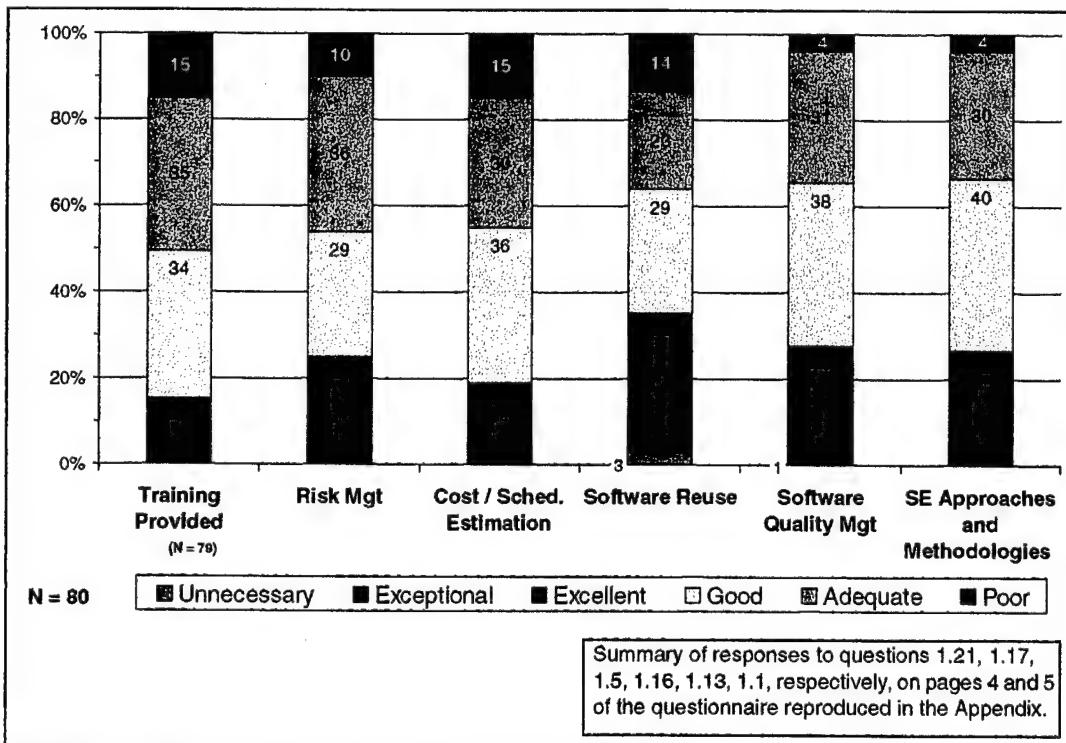
Figure 4: Key Competency Areas

The next most problematic group of key competency areas is summarized in Figure 5. Over one quarter of the respondents characterized their organizations' capabilities in these areas as being adequate or worse. Note that the response pattern for understanding "emerging software issues and technologies" closely follows response pattern for the similar category in Figure 4 of understanding the latest "software engineering approaches and methodologies." Along
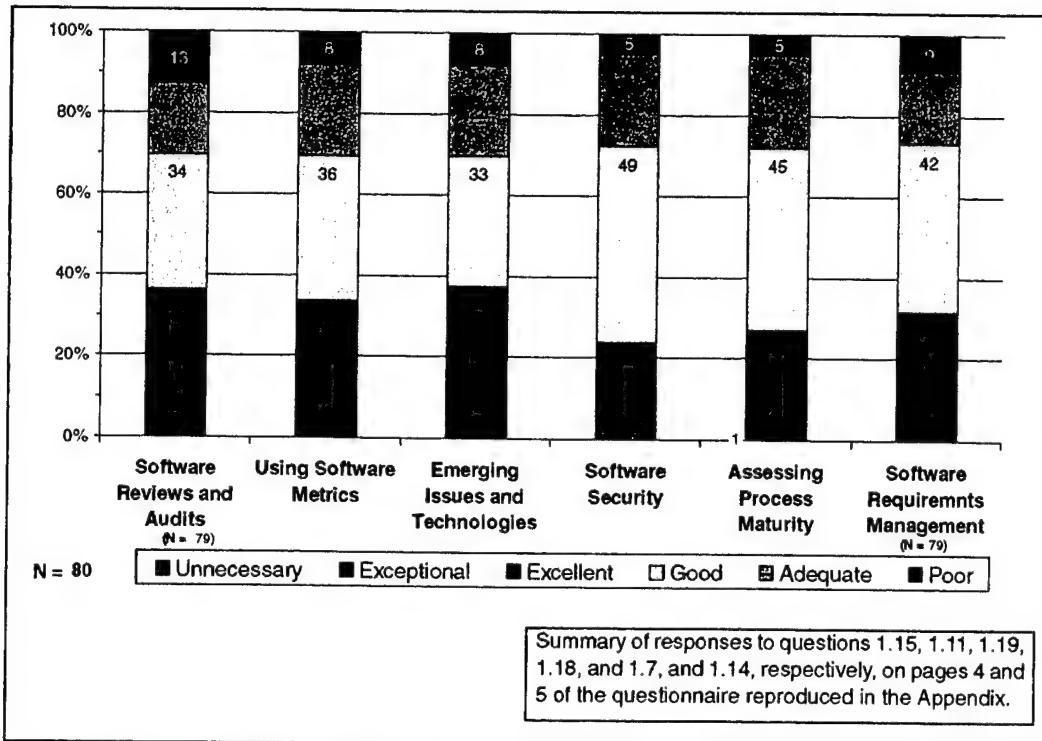
Figure 5: Key Competency Areas

with software reuse (also in Figure 4) and security, many of these PEOs and PMs recognized the importance of keeping up with changing technical trends.

Not surprisingly, requirements management makes the list of areas cited by over one fourth of these PEOs and PMs as having been adequate at best in their organizations. As we will see below, requirements issues were frequently cited as among the most difficult problems faced by acquisition organizations.

Note also that several measurement and evaluation related categories were among those key competency areas that were cited most often as having been adequate at best. In addition to "cost and schedule estimation" and "software quality management" from Figure 4, these include "software reviews and audits," "using software metrics," "assessing process maturity," and aspects of "software requirements management." Figures 6 and 7 summarize those areas that PEOs and PMs reported as being in need of relatively less improvement. In fact, the respondents rated their organization's performance for these areas as adequate to poor in less than 20% of the cases.
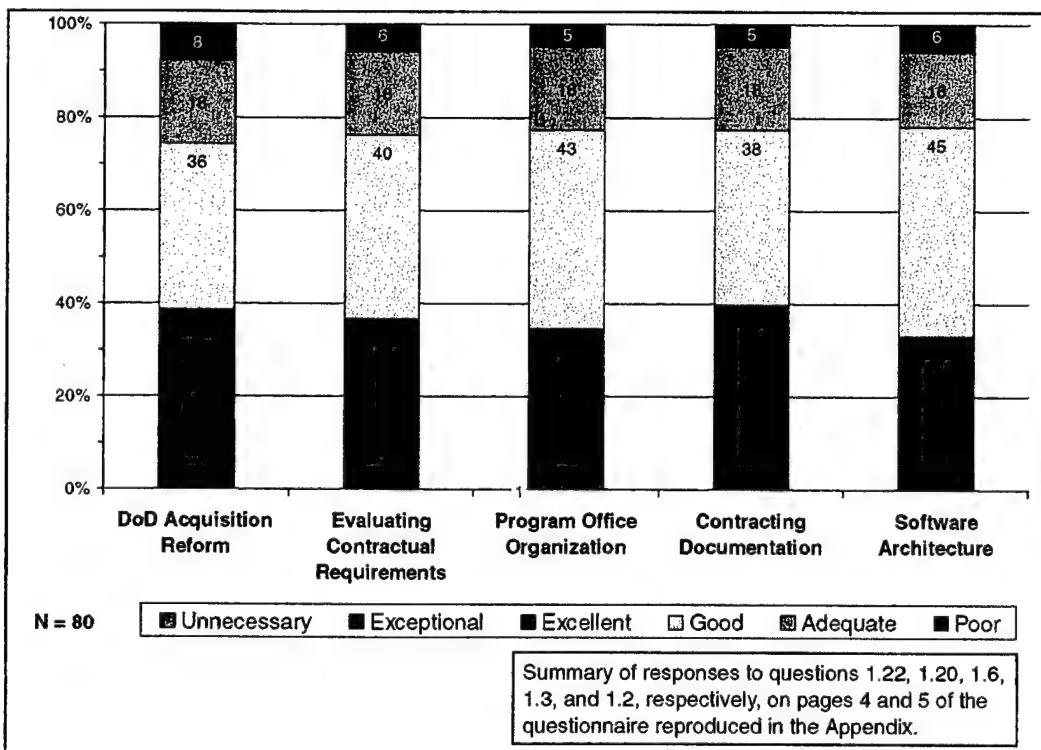
Figure 6: Key Competency Areas
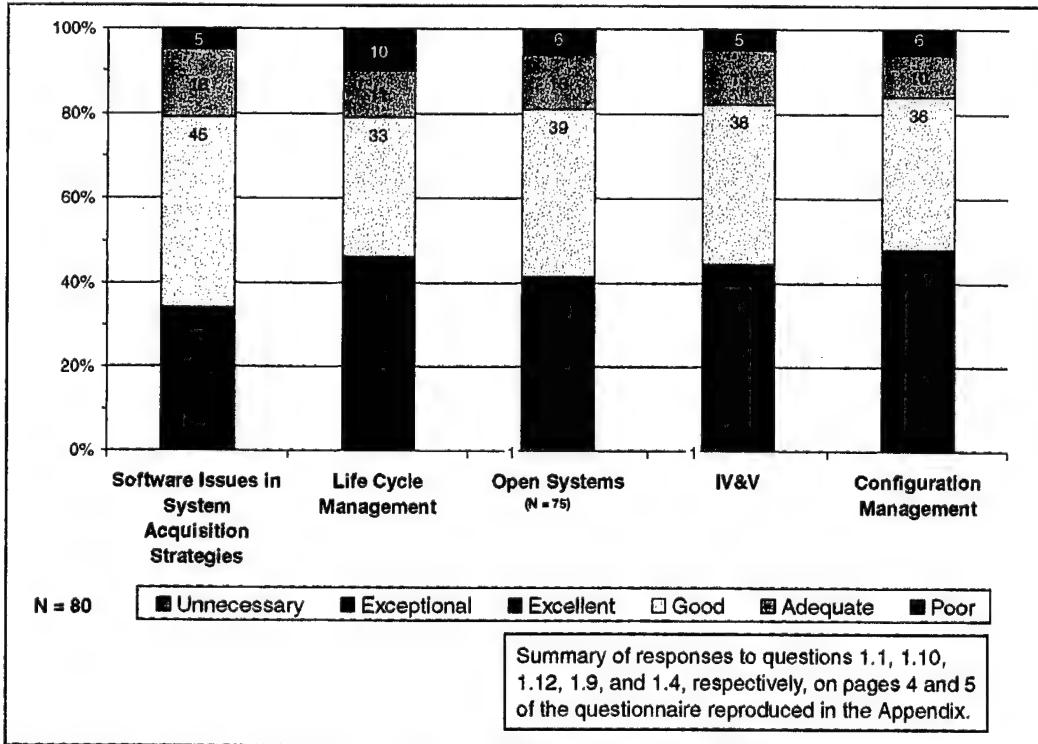
Figure 7: Key Competency Areas

3.4　Levels of Expertise

3.4.1　Previous Experience

Our respondents reported that their previous experience and training had prepared them reasonably well for their then current work in the acquisition of software intensive systems (Figure 8). Almost one half of them characterized themselves as having been extremely or very well prepared. However, the largest group (over 40%) said they were only moderately well prepared for their current duties, and just over 10% contended that they were not very well prepared.

Most of the PEOs and PMs who participated in the study said that they personally had a substantial amount of expertise in the acquisition of software intensive systems. However, they had considerably less confidence in their expertise with software acquisition and the technical aspects of software engineering (Figure 9). Almost two thirds of them characterized themselves as having substantial or even extensive expertise in managing software intensive system acquisitions. But over half told us that they had only moderate or little personal expertise in software acquisition, and over 70% said that they had comparably little expertise in the technical aspects of software engineering.

How well did it prepare them for software acquisition?

■ Extremely Well
■ Very Well
■ Moderately Well
□ Not Very Well

Summary of responses to question 2.7 on page 3 of the questionnaire reproduced in the Appendix.

N = 81
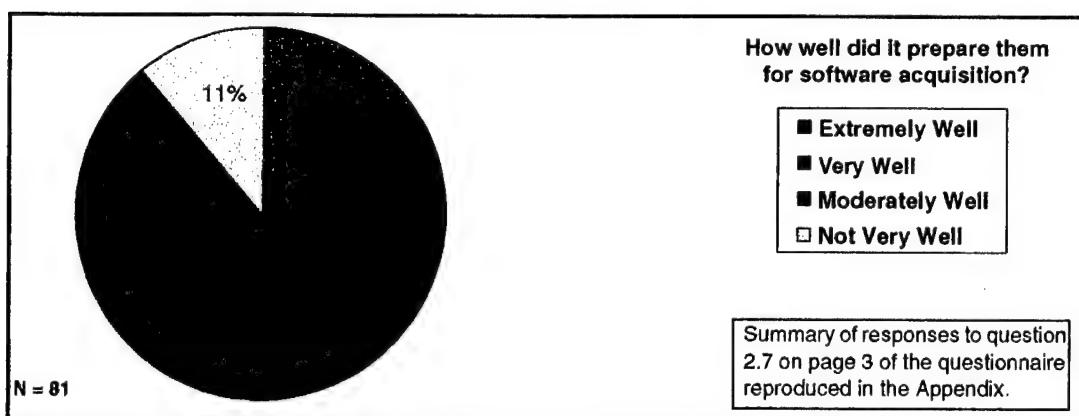
Figure 8:　Previous Experience and Training

3.4.2　Expertise Needed by Senior Management

Similar to their own personal backgrounds, most of our respondents suggested that senior management needs a broad understanding of software issues rather than detailed technical expertise. The vast majority of the survey participants said that senior management generally needs a broad, rather than detailed, understanding of technical issues in software engineering as well as of software and system acquisition (Figure 10). However, over a third also argued that senior managers need detailed technical expertise in software and system acquisition.
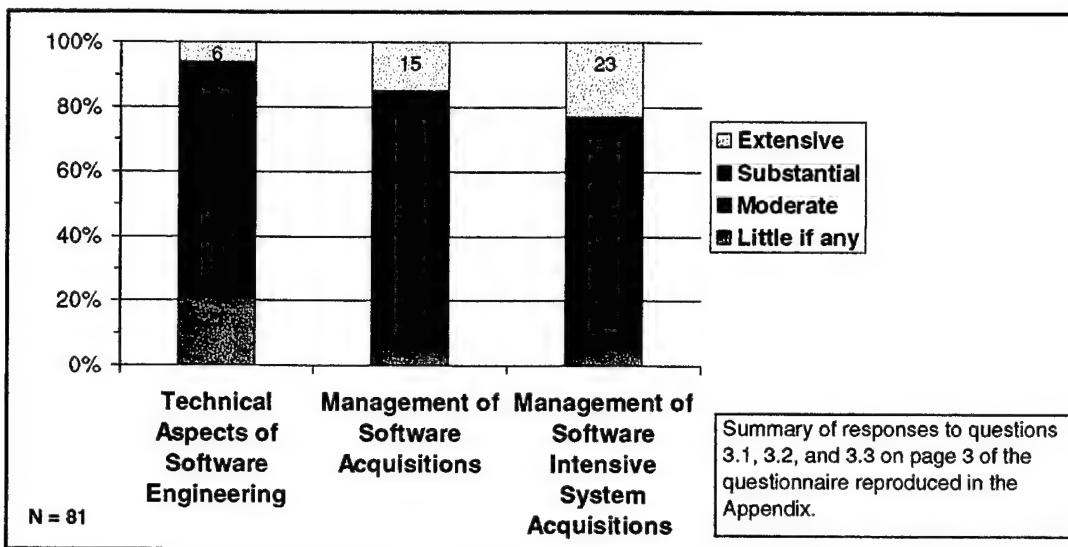
Figure 9:   Personal Expertise in Software

And almost twenty percent suggested that detailed technical knowledge is necessary in the technical aspects of software engineering as well.

3.4.3   Sources of Software Expertise

Concerns are often expressed that program offices frequently do not have sufficient, unbiased expertise available to them to support the management of the software related aspects of their acquisitions. This is so particularly when they rely primarily on the industry contractors from whom their organizations acquire their systems. However, other organizations do have comparable expertise available from their own in-house staff, from other government support organizations, or from other contractors who provide direct support to their organizations for managing systems that are acquired elsewhere.

We asked the PEOs and PMs on whom they relied for expertise about the software-related aspects of their system acquisitions. About two thirds of them said that they relied to a large extent or even almost entirely on the contractors from whom they acquired their software intensive systems (Figure 11). However, about half of them placed similar reliance on their own in-house staff, nearly as many relied on other, independent contractors, and over 40% reported that they depended similarly on government support organizations.

Not surprisingly, many program offices rely on more than one source of expertise. As also seen in Figure 11, very large majorities of the PEOs and PMs in our survey said that their organizations relied at least to some extent on all four of these potential sources of guidance.
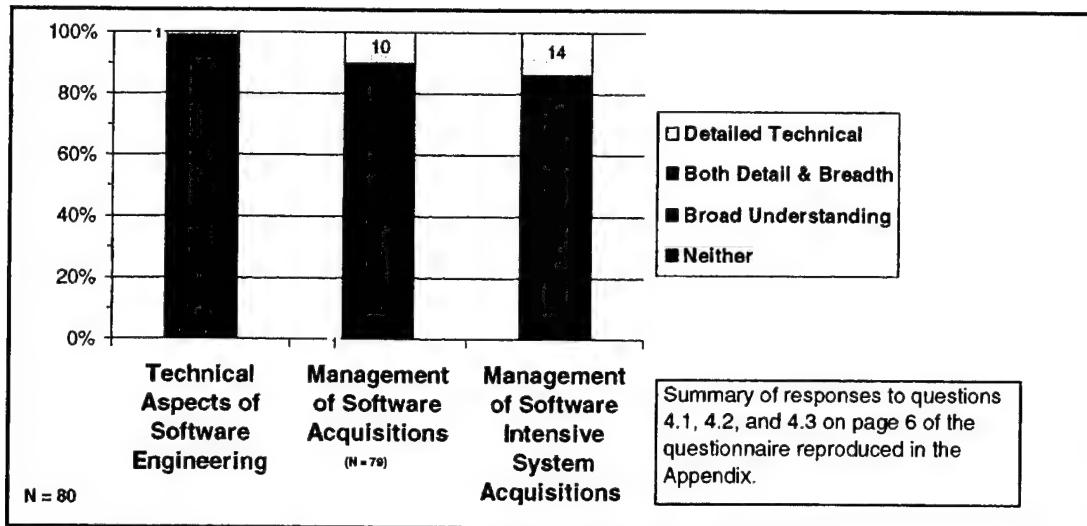
Figure 10: Software Expertise Needed by Senior Management
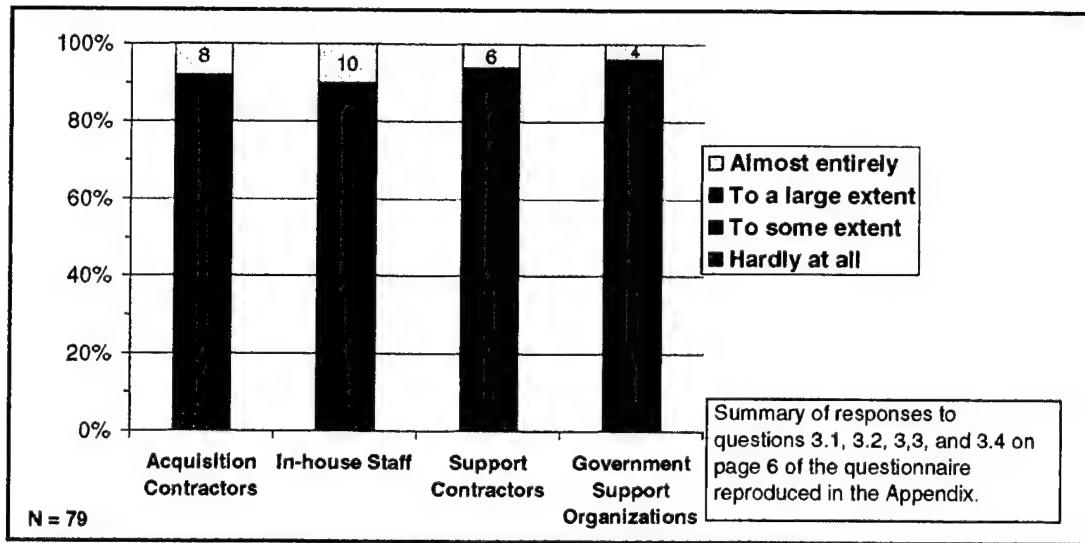
Figure 11: Sources of Software Expertise

Of course it makes a great deal of sense for organizations to seek guidance and corroboration from more than one source of expertise. Indeed, there is nothing wrong, and much right, with expecting pertinent information and expertise from competent contractors. The concern is with undue reliance on biased or otherwise limited sources of information without corroboration.

In fact, only 17% of these PEOs and PMs reported relying to a large extent or more on their suppliers exclusively for guidance about managing the software related aspects of their system acquisitions (Figure 12). However, another 25% did say that they relied to a similar extent on a second source from the other 3 sources of expertise, in addition to their suppliers. Another

17% relied extensively on only a single one of the 3 sources of expertise other than their suppliers. But that leaves 40% who said that they in fact placed similar reliance on 2 or all 3 sources of expertise other than their suppliers. Seventeen percent said they rely heavily on two sources of expertise not including their suppliers. Fifteen percent relied on two other sources in addition to their suppliers. And 9% said they relied on all four sources of expertise including their suppliers.

Acquisition Contractor Only

Acquisition Contractor Plus One Other

One Non Acquisition Contractor Only

☐ **Two or More Non Acquisition Contractors**

Summary of responses to question 3 on page 6 of the questionnaire reproduced in the Appendix.

N = 81

41%
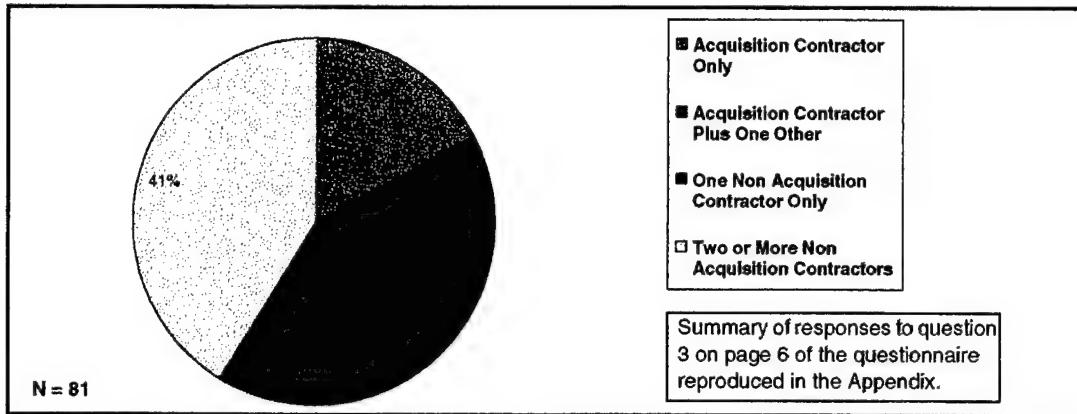
Figure 12: Multiple Sources of Expertise

Moreover, there is at least some evidence from these data that relying too heavily on acquisition contractors, and/or any other single source of information and expertise, did seem to adversely affect overall performance in acquiring the software for these systems (Figure 13). Fewer than a third (32%) of those who said that they relied exclusively on their suppliers and/or one other source of expertise other than their suppliers characterized their organizations' overall performance as being excellent or exceptional. However, almost one half of those who relied on multiple sources of software related expertise also reported that their organizations had had excellent or even exceptional success in their software acquisitions.

3.5 Training Issues

In this section we briefly review the survey participants' judgments about the need for improvement in, and the difficulties they faced in improving, education and training for software intensive systems.

3.5.1 Quality of Software Education and Training

The PEOs and PMs who completed our survey saw substantial room for improvement in then-current DoD education and training with respect to software acquisitions.
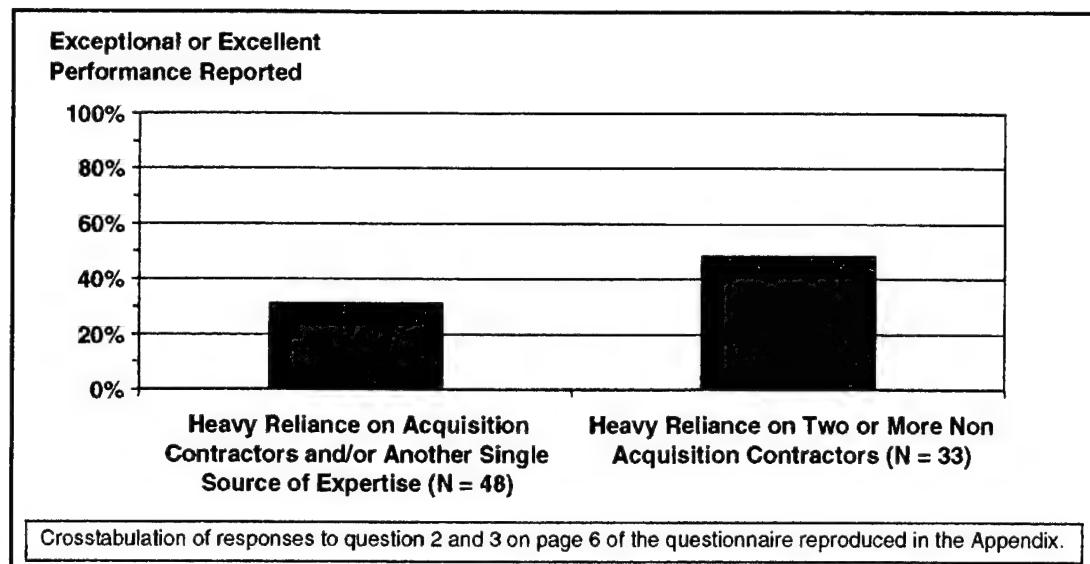
Figure 13: Performance in Acquiring Software by Sources of Software Expertise
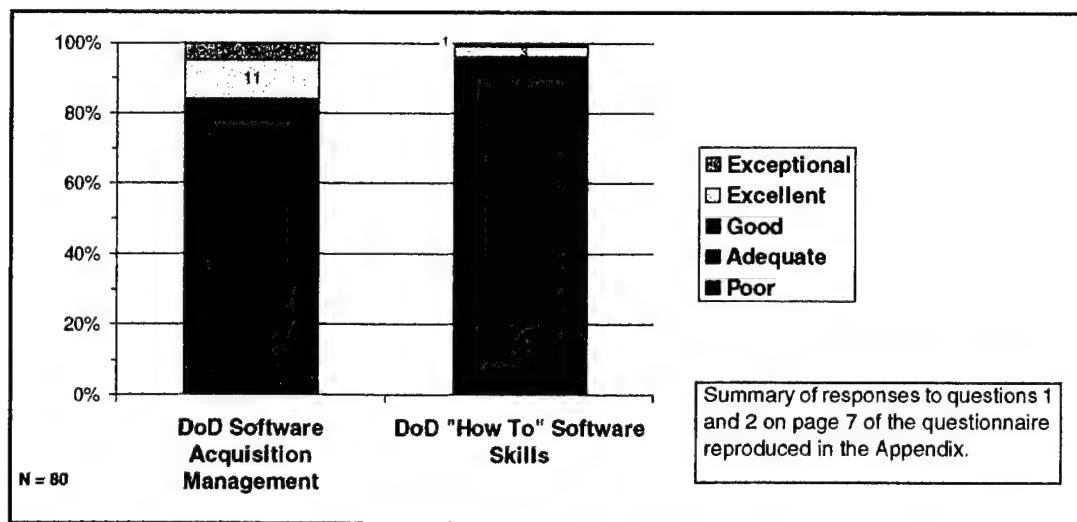
Figure 14: Quality of Software Education and Training

As seen in Figure 14, more than half of the survey respondents characterized as good or better the current DoD education and training courses in preparing their organizations for managing the software related aspects of their acquisitions. However, a large minority (46%) said it was adequate or worse, while a much smaller group (16%) asserted that it was excellent or exceptional.

When asked a more pointed question about how well then-current DoD education and training conveyed software related skills with sufficient detail and direction about how to perform

necessary tasks, the majority (over 60%) said that the situation was only adequate at best. Fewer than 5% characterized it as excellent or exceptional.

Indeed, a majority of the respondents said there "should be a separately defined career path for specialists in software acquisition management" (Figure 15). The vast majority (over 90%) agreed that "courses or comparable experience in software related management and technical topics [should] be required for all members of the acquisition corps who work on the acquisition of software intensive systems."
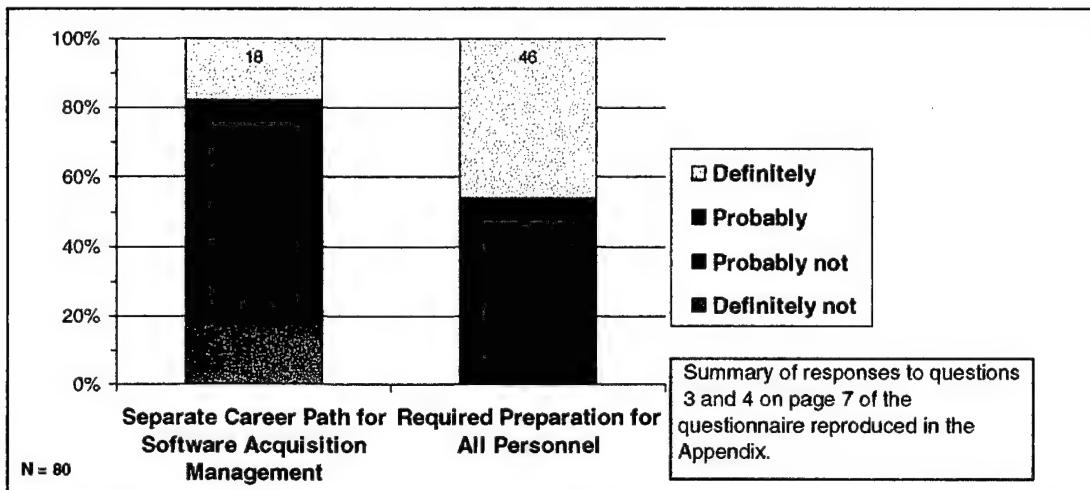
Figure 15: Need for Additional Preparation for Software Intensive Acquisitions

3.5.2 Training Delivery Mechanisms

Various "distance learning" methods and approaches have been discussed in recent years as being cost effective alternatives to traditional classroom instruction, especially for the delivery of technical training. There is also a recurrent concern in education circles with the appropriateness of pre-service versus in-service training.

We asked our participating PEOs and PMs to identify which methods their organizations currently relied on "to prepare personnel to manage the acquisition of software intensive systems." We then asked them to contrast the current situation with what delivery mechanisms they ought to use. Their responses are summarized in Figures 16 through 22.

First of all, notice that the survey respondents said that they would prefer to rely more heavily than they currently did on pre-employment training (Figure 16). Almost two thirds said that they currently relied at least "frequently" on formal education and pre-employment training. However, almost 90% said they ought to do so, with almost half saying they should "almost always" rely on such prior preparation.
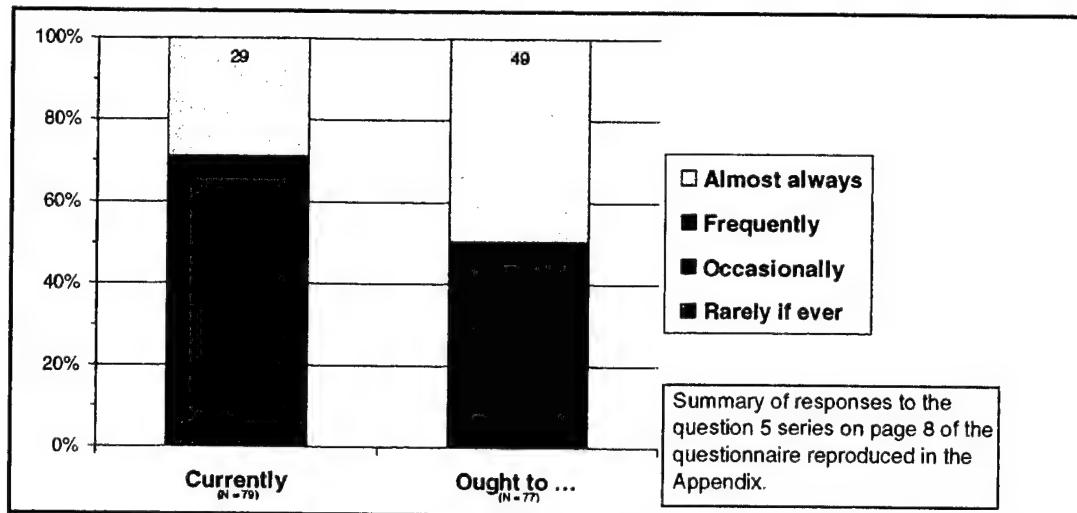
Figure 16: Training Delivery Systems: Formal Education and Pre-Employment

That said, many of the respondents stated they would like to rely more heavily on in-service training and continuing education as well (Figure 17). While a majority said they currently used continuing education and training to prepare their acquisition personnel, fewer did so than relied on pre-employment education and training. However, many of them would have liked to offer more in-service training and continuing education opportunities than they then were able to provide. Well over 90% said that they ought to provide such opportunities at least frequently.
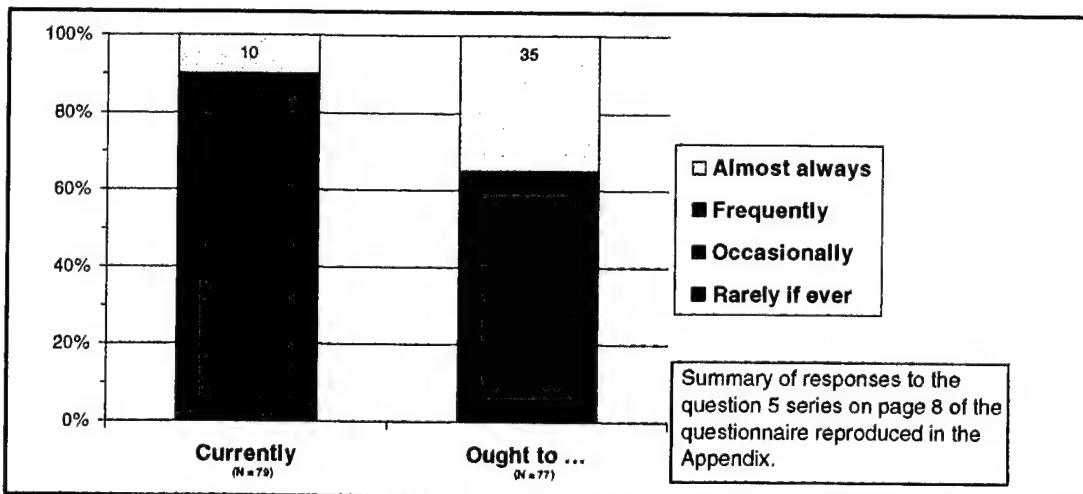
Figure 17: Training Delivery Systems: In-Service and Continuing Education

Actually, more of the survey respondents reported that their organizations currently relied on on-the-job and developmental assignments than on continuing education and in-service training (Figure 18).

However, there is little change in the number of PEOs and PMs who said they wanted to take more advantage of developmental assignments than they currently relied upon.
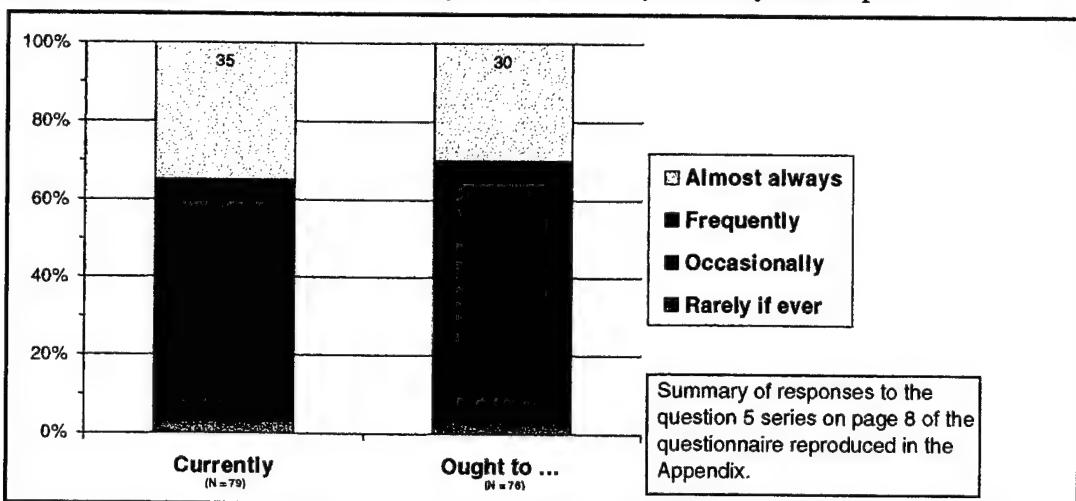
Figure 18: Training and Delivery Systems: On the Job Training and Developmental Assignments

The change between current and desired state is most pronounced for distance learning methods that we characterized as "Web based, CD ROM's, multimedia, satellite broadcasts, network and computer-based instruction, collaborative groupware." Fewer than 10% of the PEOs and PMs we surveyed reported using such methods frequently or more often (Figure 19). However, more than half said that they ought to do so at least frequently. Almost all of them said that they ought to try distance learning methods at least occasionally.
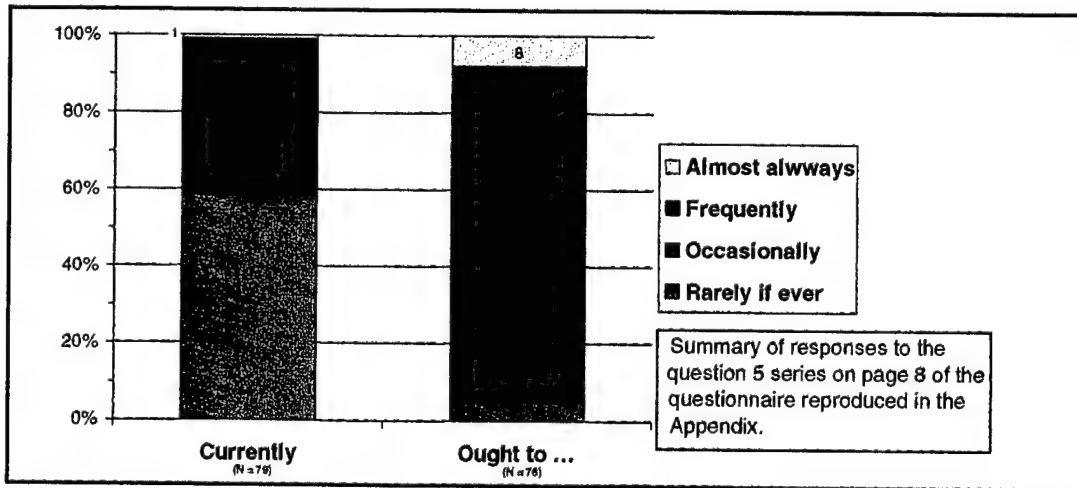
Figure 19: Distance Learning Methods
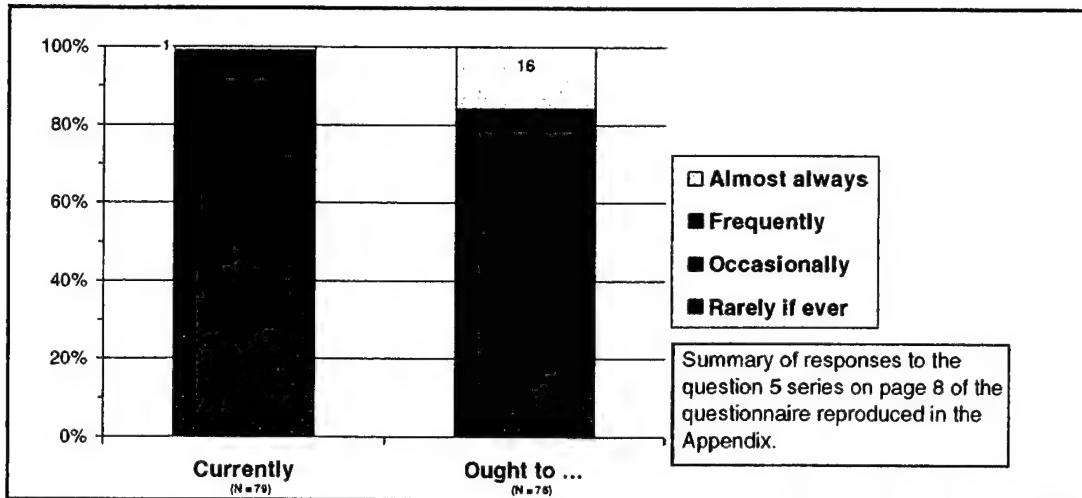
Figure 21: Training and Delivery Systems: Focused "Just-in-Time" Training

Similarly, the PEOs and PMs were considering greater use of "just in time" (JIT) training to keep their personnel up to date with rapid changes in the field (Figure 21). Not unlike the situation with distance learning methods, though, many of the respondents still appeared tentative in their judgments and were considering only occasional use of JIT training.
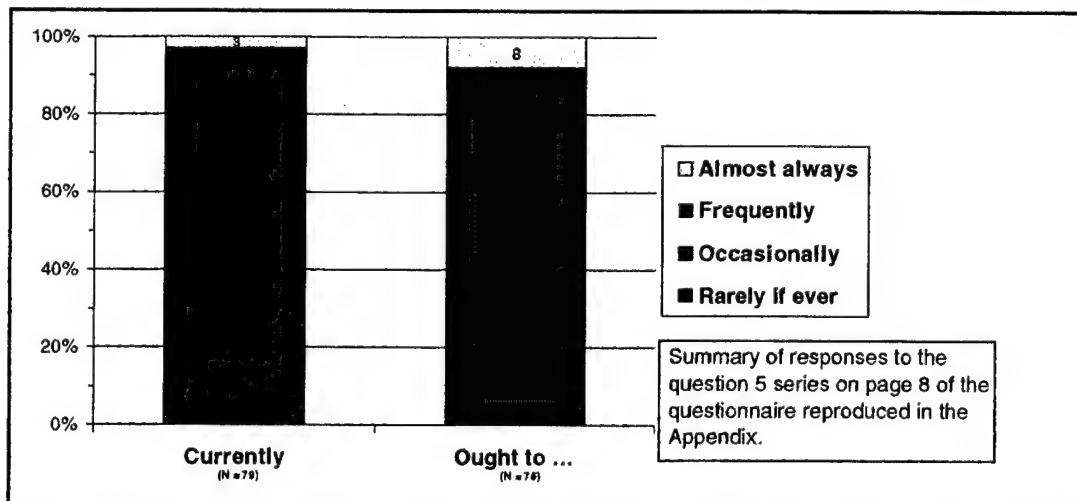
Figure 20: Training and Delivery Systems: Commercial "Off-the-Shelf" Training Courses

Commercial off-the-shelf (COTS) courses are becoming increasingly available in many areas related to information technology. We asked about the use of such alternatives "to augment or replace training provided directly by the DoD and other government agencies." As with most of the methods about which we asked, there was some increased interest in COTS courses, although with less marked change than was so for distance learning and JIT (Figure 20).

Finally, we asked about existing DoD courses. While there was interest in distance learning and other alternative delivery mechanisms, these PEOs and PMs clearly intended to continue to rely on DoD course offerings (Figure 22).
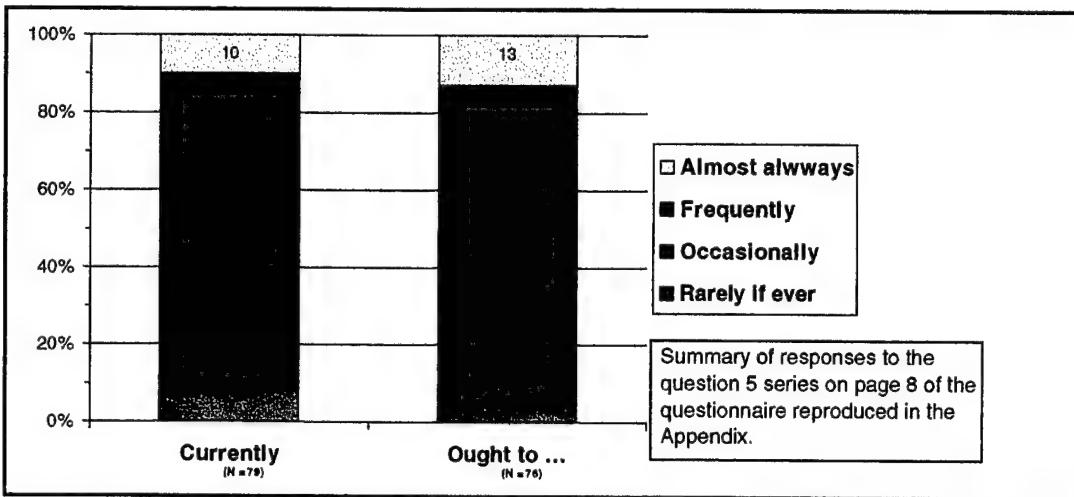
Figure 22: Training Delivery Systems: Existing DoD Courses

3.5.3 Limitations on Adequate Training

We showed the survey respondents a series of statements about limitations on an organization's ability to provide software related training to its acquisition personnel, and then asked them how well the statements applied to their organizations. Their responses are summarized in Figures 23 and 24, in rank order from the most to least frequently reported problems.

Note the most commonly reported problem was that defined organizational processes too often were abandoned during critical events and crises. Over 40% of the PEOs and PMs surveyed said that such problems adversely affected the ability of their organizations to provide software related training "to a large extent" or even "almost entirely." Almost 90% said that such described their organizations at least "to some extent." In a related vein, note also the emphasis in the remainder of Figure 24 on not having enough time or resources available to devote to training.

Finally, notice in Figure 24 that the PEOs and PMs often reported that not enough good software related courses currently were available for use by their organizations. Only about 20% of them said that such problems accurately described the situation in their organizations at least to a large extent or more, but over three quarters said their organizations were affected by such problems at least to some extent.
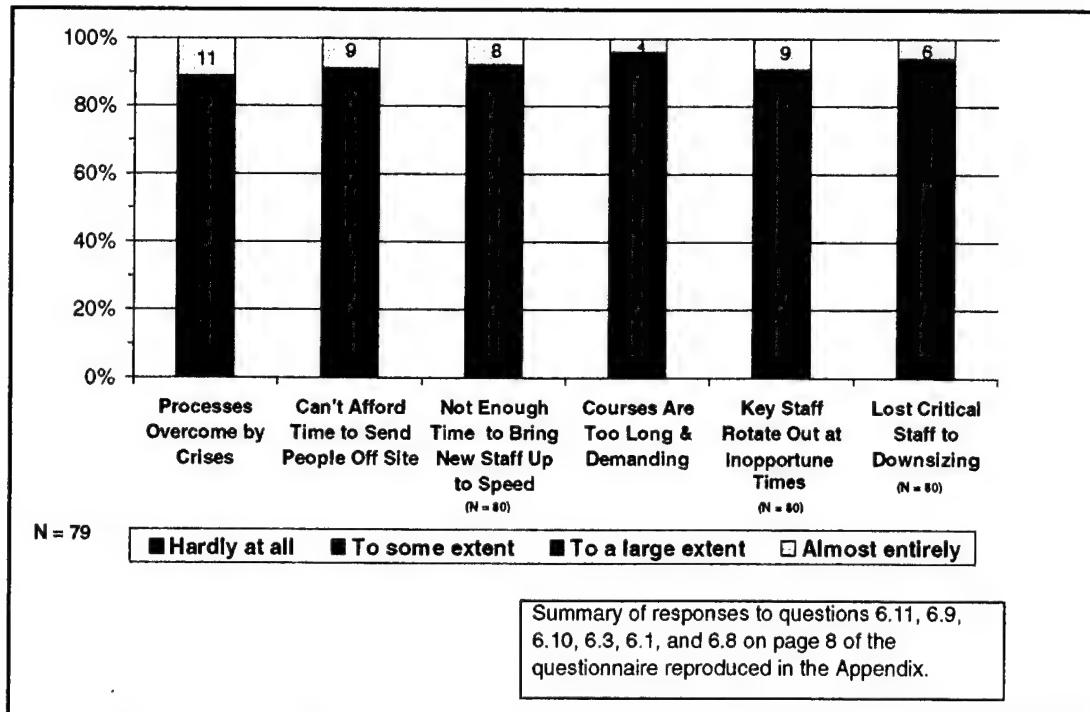
Figure 23: Limitations of Providing Adequate Training
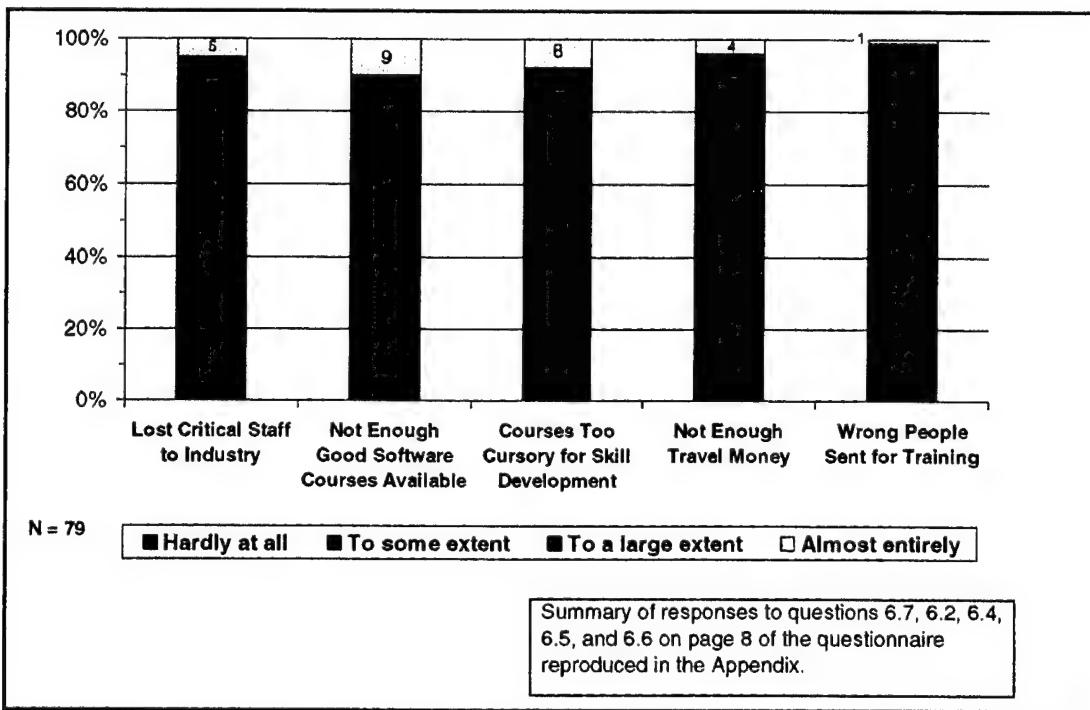
Figure 24: Limitations of Providing Adequate Training

3.6 Problems Faced in Acquiring Software Intensive Systems

In addition to the closed ended questions concerning key competency areas, we also asked the survey participants two broad, open-ended questions. After asking them to describe the one or two most difficult problems that their organizations have faced in conducting successful acquisitions, we asked them to consider the one or two things they would most like to see changed in how software intensive systems are acquired in the DoD.[3]

A variety of issues surfaced in the responses to these two questions. However, three clear themes emerged as particularly significant.

3.6.1 Requirements Development and Management

The need for better knowledge in the development and management of system and associated software requirements is evident from our respondents' free form answers. The following aggregated quotes highlight the concerns of the respondents.

The most significant problems are associated with the following:

- requirements creep
- change of requirements because of
  - customer/user *constantly* redefining and dictating requirements
  - the effect of technology changes
  - the effect of budget volatility
  - the effect of interfacing with systems outside [their] control
- poor and late definition of requirements
- managing user expectations (in terms of requirements)
- identifying and describing customer requirements

For the most part, those responses citing requirement problems attempt to point to specific causes. As an example, 7 of the 18 responses point to customer/users "dictating" and "redefining" requirements or changing requirements during system development. Others address changes due to advancing technology. There are also references to changes brought about by the existing DoD acquisition environment and funding volatility in programmatic requirements. Of course, all these types of requirement changes subsequently impact the software requirements for software intensive systems.

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3. See questions 1 and 2 on page 9 of the questionnaire reproduced in the Appendix.

If we look at the corresponding responses to the question of organizational performance in this area, we see that the rating of their organization's performance was generally good to excellent. These responses seemingly conflict with the responses to the open-ended question. However, the responses are justified somewhat if we also examine who the organization depends on for expertise. Thus, we may still expect that project staffs and acquisition managers need skills in techniques to

- develop requirements, i.e., translate user requirements into system requirements
- manage those requirements in light of user "dictated" changes, technology advances, funding constraints
- evaluate impacts of these changes on program objectives, system, and software performance

Training is one method to improve these skills.

3.6.2 Technical Background of Acquisition Managers and Staff

The following are aggregated quotes (from a total of nine responses) in the area of technical competency of managers and their staffs in managing the acquisition of software intensive systems:

- Managers of software intensive systems are chosen for their acquisition experience. They often lack any background in software and information technology issues.
- Program managers rely heavily on software contractors to meet program baselines, often with disastrous results. PMs allow this to happen because they and their staffs lack software management skills to verfiy contractor progress.
- PMs, PEOs, acquisition executives, and others in DoD acquisition management do not understand software acquisition.
- [Lack of] qualified (educated and experienced) government personnel to monitor contracts.
- Failure of many mangers to understand software is not inherently different than development and maintaining hardware.... [S]oftware developers encourage the mystique about software that discourages many managers.
- [Obtain] a PM with software experience.

These responses are consistent with those to the closed ended question about the requisite expertise senior management needs for such acquisitions (see Section 3.4.2). Indications are that senior and middle level managers need broad knowledge of software engineering principles. The depth of this knowledge should be such that these managers

- can "de-mystify" software development
- understand the similarities and differences between hardware and software development

There were also responses that described the need for senior and middle level managers needing a more in-depth knowledge of software acquisition management. The areas of knowledge should include the key competency areas noted in the survey. The depth of this knowledge should be sufficient to allow these managers

- to establish acquisition strategies that include software within the context of the system acquisition
- to make informed decisions about
  - how to select qualified contractors
  - how to manage risks that impact software
  - how to make trade-offs during contract performance period to ensure that software functionality, performance, and quality are managed.

While the responses to the open-ended questions appear much more negative than closed-ended questions in these areas, one may reasonably conclude that senior level management should have a basic knowledge of software engineering, knowledge of software acquisition management and associated issues, and a substantial knowledge of how software acquisition fits into a system acquisition context.

The lack of knowledge and experience of PMs and/or their staffs is confirmed by responses to the question of sources of software expertise. Here, many organizations reportedly depended upon the contractors who were developing the systems, rather than the in-house staff or the PMs themselves.

The specific knowledge needed spans software acquisition management key competency areas to varying degrees as expressed in the responses to the key comptency areas-oriented questions. The responses to the acquisition organization's performance were mostly adequate to good. Of course, these ratings were from the PEOs and PMs answering the questionnaire. These responses do not track well with the need for senior management to have software expertise at any level of depth. It is possible that the respondents did not have enough expertise to rate the performance of the organization in these areas.

3.6.3 Insufficient Resources

An equal number of responses (nine) to those on technical background of managers focused on the lack or insufficiency of resources. Representative statements of these concerns include the following:

- limited resources

- downsizing—not enough people to do the job right

- lack of time: with fewer people to do more work we don't have the time to train the decreasing workforce; we're relying on contractors more and more and they don't necessarily have the right experience

- obtaining qualified contract personnel in an ever-changing environment

- limited resources [in general]

These comments have direct "correlation" to the responses covering training/experience of managers and other staff members as well as to those involving the volatility of the environment in funding, personnel, and requirements.

4 Observations and Recommendations

4.1 Review

This study was conducted based in part on the recommendations in [Cavanaugh 98] which asked that the DoD perform a needs analysis of acquisition organizations to elicit their education and training requirements in terms of skill levels, skill sets, and delivery methods for software acquisition management. As discussed below, several observations and findings in that report are supported by the responses to the questionnaire used in this survey.

4.1.1 Capability Needs

In general, the questionnaire responses indicated that the senior acquisition managers who participated in our study were reasonably well satisfied with the capabilities of their organizations to acquire software intensive systems that met their cost, schedule, and performance goals. That said, they also recognized that there is room for improvement. Here, about 40% expressed reservations about their organizations' capabilities to properly handle risk management and cost and schedule estimation. Other organizational capabilities about which over one quarter of the PEOs and PMs expressed concern include software reuse, security, and keeping up with changing software engineering methodologies and emerging technologies. Several measurement and evaluation related categories also were among those key competency areas that were cited most often as having been adequate at best (Figures 4 and 5).

In addition, the respondents placed heavy emphasis on understanding software engineering, software acquisition management, and the capability to perform requirements development and, especially, requirements management. In the last case, "management" related to a spectrum of issues surrounding requirements. These issues included frequent customer changes, program/funding volatility, and technology; all contributed to constant requirement changes that the PMs had to manage. It seemed evident that skills needed to deal with these problems must be improved.

Another concern expressed by the respondents was the need for improved skills covering software acquisition management to compensate for reductions in the government workforce. More and more government acquisition organizations, represented by the participants in the survey, are relying on contractor support (such as federally funded research and development centers [FFRDCs] or system engineering technical assistance [SETA] contractors) to help in

their software-intensive system acquisitions. In this situation, the acquisition organizations must have sufficient skills to be able to obtain the qualified sources of such expertise. Some level of expertise in software acquisition management is needed by the acquisition managers or acquisition offices to ensure the skill levels of such contractor support is acquired and properly managed.

A majority said that there probably "should be a separately defined career path for specialists in software acquisition management" (Figure 15). Cavanaugh points out that there are conflicts in DoD education and training documents regarding the need or desire to establish a separate career field for software acquisition management. The difference may be that our responses are from the people who need the capability, rather than from the Office of the Secretary of Defense (OSD).

Over 90% agreed that "courses or comparable experience in software related management and technical topics [should] be required for all members of the acquisition corps who work on the acquisition of software intensive systems."

4.1.2   Training Improvement

The PEOs and PMs who completed our survey saw substantial room for improvement in DoD education and training with respect to the management of software-intensive system acquisitions. While over half of them characterized DoD education and training courses as doing a good or better job in preparing their organizations for managing the software related aspects of their acquisitions, a large minority (46%) said it was adequate or worse (Figure 14). This compares with [Cavanaugh 98] key findings that state that the primary DoD software acquisition management courses

- do not provide sufficient informational content to cover a majority of the selected topic areas in this review, or those in the Software Acquisition Management Review Team (SAMERT) key competency areas [SAM 94, SAM 96]
- do not provide sufficient informational content to achieve recommended Bloom's Taxonomy levels as described in the SAMERT Report[4]
- do not incorporate effective practices with respect to key competency areas in sufficient depth to explain how to accomplish software acquisition management

Cavanaugh notes that the required software acquisition management training from the Defense Acquisition University (DAU) may not be available to the personnel responsible for software acquisition management for projects (e.g., SETA contractors). This is a concern because many

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4. The SAMERT Report [SAM 94] details Bloom's taxonomy levels.

of the respondents here relied upon such support contractors to provide the necessary software engineering and software acquisition management skills for their acquisitions.

In response to a more pointed question about how well DoD education and training conveyed detailed information about how to perform specific software related tasks, over 60 percent said that the situation was only adequate at best. Cavanaugh points out that information currently available on effective practices (i.e., "how-to" methods) to implement and take advantage of acquisition reform initiatives is not sufficient to help acquisition managers, specifically in the software acquisition management area.

4.1.3   Training Delivery Improvement

A large number of respondents, just over 50%, described the training opportunities provided by their organizations as being poor or adequate at best. Many respondents were considering relying more on various distance learning methods (Figure 19), just in time training (Figure 21), and commercial off-the-shelf courses (Figure 20). However, while there was clear interest in alternative delivery mechanisms, the PEOs and PMs also intended to continue to rely on DoD course offerings (Figure 22).

As a potential solution, Cavanaugh points out that "currently, the use of alternative delivery methods for educating and training the acquisition workforce is not fully exploited by DAU [OUSD 97b]. (However, a concept plan and an implementation plan do exist to implement a technology-based education and training program within DAU [DAU 97a, DAU 97b].)"

4.2   Recommendations

The responses to the questionnaire suggest the following recommendations.

- Reassess the current Acquisition Career Development Program certification requirements to provide a more focused and structured career management curriculum with defined skill sets and minimum technical competencies related to software acquisition management. This reassessment may also identify the need for a separate software acquisition management career field as part of Acquisition Career Development Program certification.
- Conduct a study to achieve the following goals:
  - Determine the best means of providing the in-depth knowledge, including both "how to's" and lessons learned, required for achieving the higher levels of Bloom's Taxonomy [SAM 94, SAM 96] as well as the advanced levels of software acquisition management and continuing education. At a minimum, this study should consider

alternative delivery mechanisms, just-in-time training, long-term certificate programs, and specialized training focusing on specific aspects of software acquisition management.

- Analyze alternative delivery mechanisms to determine which would best fulfill software acquisition management's need for ensuring that workforce training is kept up to date, providing on-site training, and updating already certified professionals.

- As in Cavanaugh, we suggest that DoD conduct a feasibility study of providing specific skills levels for software acquisition managers by training both software engineering and software acquisition management in an integrated, long-term certification program. One way of achieving this cross-discipline competency is by training both software engineering and software acquisition in an integrated environment. (The concept of an integrated environment has already been applied at the Air Force Institute of Technology in its Software Professional Development Program.)

- Finally, we have no comparable evidence about the judgments of less senior acquisition personnel. The study does provide insight and identify issues from the perspective of PEOs and PMs, but it is not necessarily generalizable to the wider DoD acquisition community. Follow-on surveys of less senior personnel should be conducted to provide additional insights into problem areas and suggest potential solutions to software-intensive systems acquisition management needs.

Appendix: Questionnaire

A copy of the survey questionnaire follows.

Acquisition of Software Intensive Systems in the United States Government

Purpose

This document contains questions about your experiences in acquiring software intensive systems for use in DoD organizations and other federal agencies. The results will be used to help formulate plans for education and training to improve the acquisition of software-intensive systems. Your answers will be invaluable to help us better understand the needs of the acquisition workforce.

Instructions

You are part of a carefully chosen sample. It is extremely important that we receive your candid and personal answers in order for the results to be accurate and useful.

The questionnaire should take about thirty minutes of your time. Please complete it as soon as you can -- right away if you can make the time.

Confidentiality

Your answers will be held in the strictest of confidence. Information that can identify you and your organization will be used for administrative purposes of this study only. Your answers will be used in summary statistical form. Specific answers will never be identified by organization or individual.

Thank you for your help.

Software Engineering Institute
Carnegie Mellon University
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Your Background in the Acquisition of Software Intensive Systems

- By "software intensive systems" we mean systems where some, though not necessarily all, functions of the system are implemented through or rely on software -- AIS, weapons systems, C^3IEW.
- By "acquisition" we mean the process of obtaining through contract. Contracts (formal or informal) are binding agreements between two or more parties that establish the requirements for the products or services to be acquired. Acquisition starts with planning of the system to be acquired and continues through final delivery of products and services.
- By "software acquisition management" we mean the control and direction of the technical and management decisions that affect the acquisition of the software in acquisitions of software-intensive systems.

1   First of all, what kind of software intensive systems have you participated in acquiring?
    (Please select as many as apply)

      ☐   AUTOMATED INFORMATION SYSTEMS -- e.g., management information systems supporting business operations such as payroll, inventory, or logistics

      ☐   WEAPONS SYSTEMS -- e.g., with real-time process control or guidance systems for avionics or radar; embedded software running in electronic devices, vehicles, missiles or air craft

      ☐ C^3IEW -- e.g., decision support systems, mission planning, communications systems, or maneuver control

      ☐   OTHER -- e.g., simulations, compilers, configuration management tools, cost estimation tools, personal computer applications, pattern recognition, expert systems *(Please describe briefly)*

2   How well has your previous experience or training prepared you for your current work in the acquisition of software intensive systems? *(Please select one)*

      ☐   EXTREMELY WELL

      ☐   VERY WELL

      ☐   MODERATELY WELL

      ☐   NOT VERY WELL

2.1 What specifically in your previous experience or training <u>best</u> prepared you for your current work (e.g., job experience, particularly good training courses, mentoring, previous work on software acquisitions)? *(Please describe briefly)*

2.2 In what ways and in what areas could you have been <u>better</u> prepared for your current work in the acquisition of software intensive systems (e.g., better training or mentoring, more background in software engineering)? *(Please describe briefly)*

3 How would you describe your personal expertise in ...? *(Please select one for each)*

	EXTENSIVE	SUBSTANTIAL	MODERATE	LITTLE IF ANY
3.1 Technical aspects of software engineering....................................	☐	☐	☐	☐
3.2 Management of <u>software</u> acquisitions...	☐	☐	☐	☐
3.3 Management of the acquisition of software intensive <u>systems</u>	☐	☐	☐	☐

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> • By "acquisition organization" we mean a Program Management Office or other entity that has the oversight responsibility for one or more acquisitions of software intensive systems.
> • When thinking about your organization, please answer for the acquisition organization(s) that you actually work in or that you support - not for the larger entity of which it may be a part.

1 Following is a list of areas related to the management of software acquisition that may impact an organization's ability to successfully acquire software intensive systems. How would you rate the capability of your acquisition organization in each area? Or is that capability unnecessary in your organization? *(Please select the best answer for each)*

		EXCEPTIONAL	EXCELLENT	GOOD	ADEQUATE	POOR	UNNECESSARY
1.1	Developing system acquisition strategies that address software issues (e.g., strengths and weaknesses of current strategies, impact on project planning and engineering methods)	☐	☐	☐	☐	☐	☐
1.2	Incorporating software architecture concepts into acquisition RFP's and contracts (e.g., relationships of software to system architectures, and architecture to software design)	☐	☐	☐	☐	☐	☐
1.3	Handling contracting related documentation (e.g., work break-down structure for software, laws and regulations related to SOW and RFP, data and intellectual property rights, commercial and DoD best practices)	☐	☐	☐	☐	☐	☐
1.4	Understanding configuration management processes and practices (e.g., synchronization of hardware and software baselines)	☐	☐	☐	☐	☐	☐
1.5	Making estimates of software costs and schedules (e.g., strengths and weaknesses of estimation methods and models, life cycle cost and schedule reporting, validation/assessment of fidelity of cost estimates)	☐	☐	☐	☐	☐	☐
1.6	Understanding software issues in program/project office organization and relationships (e.g., staffing, matrix support groups, resource management, project control and tracking, end user involvement, intergroup coordination, corrective actions)	☐	☐	☐	☐	☐	☐
1.7	Assessing maturity of software acquisition and development processes	☐	☐	☐	☐	☐	☐
1.8	Understanding the latest software engineering approaches and methodologies and incorporate them into the acquisition (e.g., strengths and weaknesses of functional, object oriented, and other current, approaches effect of design approach on software and system engineering, CASE selection and use)	☐	☐	☐	☐	☐	☐
1.9	Understanding concepts of independent verification and validation and incorporate them into the management of the software acquisition	☐	☐	☐	☐	☐	☐
1.10	Understanding life cycle management (e.g., as it is affected by areas such as DoD life cycle guidance, outsourcing, and post deployment software support)	☐	☐	☐	☐	☐	☐
1.11	Determining how and when to use metrics (e.g., to gain visibility into software and system development processes and products)	☐	☐	☐	☐	☐	☐
1.12	Incorporating Open Systems concepts and practices into the management of the acquisition	☐	☐	☐	☐	☐	☐
1.13	Incorporating software quality management concepts and practices into the acquisition (e.g., software quality attributes, clean room, peer reviews, software quality assurance planning and techniques)	☐	☐	☐	☐	☐	☐

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1 (continued) How would you rate the capability of <u>your</u> acquisition organization in each area? Or is that capability unnecessary in your organization? *(Please select the best answer for each)*

	EXCEPTIONAL	EXCELLENT	GOOD	ADEQUATE	POOR	UNNECESSARY
1.14 Managing software requirements (e.g., requirements elicitation/ definition, user involvement, baselines and traceability, critical measures of effectiveness, managing changing requirements)	☐	☐	☐	☐	☐	☐
1.15 Incorporating software reviews and audits into the acquisition (e.g., critical software life cycle reviews, relationship of software and system reviews)	☐	☐	☐	☐	☐	☐
1.16 Incorporating reusable software into system development (e.g., considering cost factors, software support transition issues, outsourcing, and post deployment software support)	☐	☐	☐	☐	☐	☐
1.17 Performing software acquisition risk management for the acquisition organization	☐	☐	☐	☐	☐	☐
1.18 Incorporating software security concepts and practices into the management of the acquisition	☐	☐	☐	☐	☐	☐
1.19 Understanding emerging issues and technologies that affect software (e.g., Joint Technical Architecture, domain and product line engineering, state of the art of software technology, interoperability issues)	☐	☐	☐	☐	☐	☐
1.20 Evaluating software related processes, products, and services to determine if contractual requirements are being satisfied	☐	☐	☐	☐	☐	☐
1.21 Providing appropriate training to personnel who manage software acquisitions	☐	☐	☐	☐	☐	☐
1.22 Understanding the implications on the acquisition of software intensive systems of DoD acquisition reforms (e.g., integrated product and process teams, electronic commerce and data interchange, oversight reduction, earned value management, or the Defense Acquisition Deskbook)	☐	☐	☐	☐	☐	☐

1.23   Are there any other important areas that you think belong in this list? How would you rate the capability of your acquisition organization in those areas? *(Please describe briefly)*

2   Overall, how would you rate the performance of your organization in acquiring the <u>software</u> for the systems you acquire (e.g., meeting schedule and budget commitments, and the technical performance once deployed of the software)? *(Please select one for each)*

    ☐   EXCEPTIONAL

    ☐   EXCELLENT

    ☐   GOOD

    ☐   ADEQUATE

    ☐   POOR

3   On whom does your organization rely for expertise about managing the software related aspects of its acquisition(s)? *(Please select one for each)*

	ALMOST ENTIRELY	TO A LARGE EXTENT	TO SOME EXTENT	HARDLY AT ALL
3.1 In-house staff in the acquisition organization	☐	☐	☐	☐
3.2 Other government organizations that are used to support the organization's software intensive acquisitions	☐	☐	☐	☐
3.3 The industry contractors from whom the organization acquires software intensive systems	☐	☐	☐	☐
3.4 Other contractors that provide direct support to the organization..	☐	☐	☐	☐

4   What level of expertise do you think senior management needs in ... ?
(Please select the best answer for each)

	DETAILED TECHNICAL	BROAD UNDERSTANDING	LARGE PARTS OF BOTH	NEITHER
4.1 Technical aspects of software engineering	☐	☐	☐	☐
4.2 Management of <u>software</u> acquisitions	☐	☐	☐	☐
4.3 Management of the acquisition of software intensive <u>systems</u>	☐	☐	☐	☐

Training Issues

1   In general, how good a job do you think current DoD education and training does in preparing your organization for managing the software related aspects of your acquisitions? *(Please select one)*

- ☐ EXCEPTIONAL
- ☐ EXCELLENT
- ☐ GOOD
- ☐ ADEQUATE
- ☐ POOR

2   How well do you think current DoD education and training convey <u>software</u> related skills -- with sufficient detail and direction about <u>how</u> to perform necessary tasks? *(Please select one)*

- ☐ EXCEPTIONAL
- ☐ EXCELLENT
- ☐ GOOD
- ☐ ADEQUATE
- ☐ POOR

3   Do you think that there should be a separately defined career path for specialists in software acquisition management? *(Please select one)*

- ☐ DEFINITELY
- ☐ PROBABLY
- ☐ PROBABLY NOT
- ☐ DEFINITELY NOT
- ☐ DON'T KNOW

4   Should courses or comparable experience in software related management and technical topics be required for all members of the acquisition corps who work on the acquisition of software intensive systems? *(Please select one)*

- ☐ DEFINITELY
- ☐ PROBABLY
- ☐ PROBABLY NOT
- ☐ DEFINITELY NOT
- ☐ DON'T KNOW

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5 Which of the following does your organization <u>currently</u> rely on to prepare personnel to manage the acquisition of software intensive systems? What <u>ought</u> you rely on ... ? *(Please select one for each)*

|		Currently ...				Ought to ...			
		ALMOST ALWAYS	FREQUENTLY	OCCASIONALLY	RARELY IF EVER	ALMOST ALWAYS	FREQUENTLY	OCCASIONALLY	RARELY IF EVER
5.1	Formal education and pre-employment training	☐	☐	☐	☐	☐	☐	☐	☐
5.2	In-service continuing education and short courses	☐	☐	☐	☐	☐	☐	☐	☐
5.3	On the job training and developmental assignments	☐	☐	☐	☐	☐	☐	☐	☐
5.4	"Distance learning" methods (e.g., web based, CD ROMs, multimedia, satellite broadcasts, network and computer based instruction, collaborative groupware)	☐	☐	☐	☐	☐	☐	☐	☐
5.5	Focused "just in time" training.........................	☐	☐	☐	☐	☐	☐	☐	☐
5.6	Commercial off-the-shelf courses to augment or replace training provided directly by the DoD and other government agencies........................	☐	☐	☐	☐	☐	☐	☐	☐
5.7	Existing DoD courses.......................................	☐	☐	☐	☐	☐	☐	☐	☐

6 Following is a list of statements that are sometimes made about an organization's ability to obtain adequate training about software related aspects of system acquisition. How well do these statements apply to <u>your</u> organization? *(Please select one for each)*

		ALMOST ENTIRELY	TO A LARGE EXTENT	TO SOME EXTENT	HARDLY AT ALL
6.1	Key staff rotate out of the organization at inopportune times before the acquisition is finished..	☐	☐	☐	☐
6.2	There aren't enough good training courses available to properly prepare our staff for their software acquisition management duties	☐	☐	☐	☐
6.3	Existing courses are too long and demanding. Our staff can't spare the time to attend them..	☐	☐	☐	☐
6.4	Exisiting courses are too cursory. They're not not long enough to convey usable information or help people develop new skills.......	☐	☐	☐	☐
6.5	We don't have enough travel or other discretionary money available to send people for the training they need........................	☐	☐	☐	☐
6.6	We sometimes send the wrong people for training	☐	☐	☐	☐
6.7	The organization has lost critical staff to better paying jobs in industry..	☐	☐	☐	☐
6.8	The organization has lost critical staff to downsizing of the acquisition workforce..	☐	☐	☐	☐
6.9	We can't afford the time to send key personnel to training courses; we need to keep them on-site and on the job	☐	☐	☐	☐
6.10	The organization doesn't spend enough time bringing new staff up to speed. Critical time and resources are wasted rediscovering what is already well known and understood	☐	☐	☐	☐
6.11	Despite the best of intentions, defined processes and procedures are overcome by events and crises. Other things take priority......	☐	☐	☐	☐

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Problems Faced in Acquiring Software Intensive Systems

1　Overall, what are the one or two <u>most</u> <u>difficult</u> problems that your organization has faced in conducting successful acquisitions of software intensive systems? *(Please describe fully)*

2　If you could change one or two things about how software intensive systems are acquired in the DoD, what would they be? *(Please describe fully)*

Acquisition of Software Intensive Systems in the United States Government
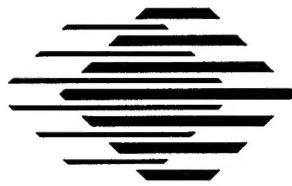
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13. ABSTRACT (maximum 200 words)

Acquisitions of software intensive systems by the Department of Defense (DoD) have often suffered from poor product quality, cost overruns, and schedule slips. In turn, these problems have frequently been linked to the inability of project offices to successfully manage the acquisition of the software components of the systems.

There have been a number of efforts to provide the necessary education and training to improve the skills and capabilities of managers for software intensive acquisitions. However, acquisition problems remain pervasive in the DoD [Cavanaugh 98].

More must be known about the causes and underlying issues surrounding these problems. Specifically, the needs of the acquisition management offices must be better understood to help them improve. This includes a better understanding of how education and training can improve the individual manager's skills and competency related to acquiring such systems.

To elicit these needs, the Software Engineering Institute (SEI) conducted a survey of senior acquisition managers. The survey focused on the performance of their organizations, particularly with respect to a series of skills and competency areas that may affect an organization's ability to successfully acquire software intensive systems.

Results indicate that the program executive officers (PEOs) and program managers (PMs) who completed the survey were reasonably well satisfied with the capabilities of their organizations to acquire software intensive systems. In many cases, however, the source of the expertise for such acquisitions were contractors either supporting the organizations or the prime contractors developing these systems. Comparable expertise often was unavailable in government acquisition organizations themselves. From this fact, the need for government expertise in these acquisitions was noted. In addition, the survey queried participants on the best way to obtain this expertise through education and training.

Finally, recommendations derived from survey results are offered to increase software acquisition education and training opportunities for managers.

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